DIFFRACTIVE PARTON DISTRIBUTIONS AND THE SATURATION MODEL

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We construct diffractive parton distributions in the model of DIS diffraction in which the diffractive state is formed by the $q\bar{q}$ and $q\bar{q}g$ components. The interaction of such systems with the proton is described by the dipole cross section given by the saturation model. We find Regge factorization property with the measured at HERA depenedence on energy. The found parton distributions are evolved with the DGLAP evolution equations to make a comparison with the data.

1 Introduction

Collinear factorization proved for diffractive DIS [1] allows to define diffractive quark and gluon distributions through the relation to the diffractive structure function, e.g. in the leading $\log(Q^2)$ approximation

$$F_2^{D(3)} = 2 \sum_q e_q^2 \, \beta \, q^D(\beta, Q^2, x_{I\!P}), \tag{1}$$

where $q^D = \bar{q}^D$. This relation concerns only the leading twist description. The diffractive parton distributions (DPD) obey the DGALP evolution equations. In the Ingelman-Schlein approach to DIS diffraction *Regge factorization* is additionally assumed

$$q^D(\beta, Q^2, x_{I\!P}) = f(x_{I\!P}) \, f_q(\beta, Q^2), \tag{2}$$

where $f(x_{I\!P})$ is related to the soft pomeron flux [2,3]. In an alternative approach, the detailed description of diffractive processes is achieved by modelling the diffractive final state as well as its interaction with the proton starting from perturbative QCD [4]. Such an analysis goes beyond the leading twist description and Regge factorization for the DPD is not assumed. The problem which is faced in this approach is the strong sensitivity to nonperturbative
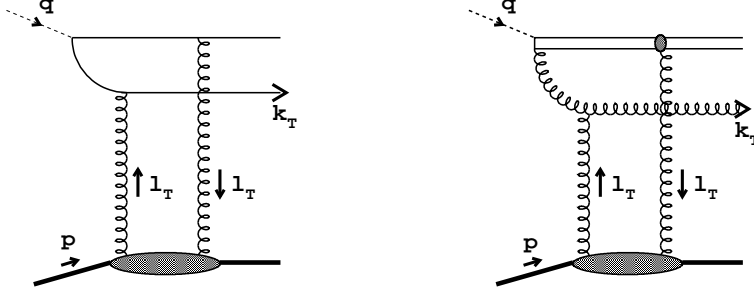
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Figure 1. *The diffractive $q\bar{q}$ and $q\bar{q}g$ contributions to $F_2^{D(3)}$.*

effects due to the dominance of the aligned jet configurations. Thus, a model of soft or semihard interactions between the diffractive system and the proton is necessary.

In our analysis we use the saturation model [5] for this purpose which turned out to be successful in the description of inclusive and diffractive DIS data. Extracting the DPD we are able to make a contact with the Ingelman-Schlein approach. We find Regge factorization with the measured energy dependence and quantify the role of the higher twist contribution.

2 Diffractive parton distributions

Following the idea of the analysis [6], the diffractive structure function $F_2^{D(3)}$ is the sum of the three contributions shown in Fig. 1, the $q\bar{q}$ production from transverse and longitudinal photons, and the $q\bar{q}g$ production,

$$F_2^{D(3)}(\beta, Q^2, x_{I\!P}) = F_{q\bar{q}}^T + F_{q\bar{q}}^L + F_{q\bar{q}g}^T, \tag{3}$$

where T and L refer to the polarization of the virtual photon. For the $q\bar{q}g$ contribution only the transverse polarization is considered, since the longitudinal counterpart has no leading logarithm in Q^2. In this approach, the diffractive $q\bar{q}$ and $q\bar{q}g$ systems interact with the proton like in the two gluon exchange model with the coupling to the proton described by the dipole cross section given by the saturation model [5].

We find the diffractive parton distribution in such a model by extracting the leading twist part, i.e. that which depends logarithmically on Q^2, from

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Eq. (3). In this case only $F_{q\bar{q}}^T$ and $F_{q\bar{q}g}^T$ contribute since the longitudinal contribution $F_{q\bar{q}}^L$ is higher twist [6] suppressed by the additional power of $1/Q^2$.

The computation of the diffractive structure function (3) was presented in [7]. Here we quote only the final results. The transverse $q\bar{q}$ part is given by

$$F_{q\bar{q}}^T = \frac{3}{64\pi^4 B_D\, x_{I\!P}} \sum_q e_q^2\, \frac{\beta^2}{(1-\beta)^3} \int_0^{\frac{Q^2(1-\beta)}{4\beta}} dk^2\; \frac{1 - \dfrac{2\beta}{1-\beta}\dfrac{k^2}{Q^2}}{\sqrt{1 - \dfrac{4\beta}{1-\beta}\dfrac{k^2}{Q^2}}}\; \phi_1^2, \quad (4)$$

where

$$\phi_1 = \phi_1(k,\beta,x_{I\!P}) = k^2 \int_0^\infty dr\, r\, K_1\left(\sqrt{\frac{\beta}{1-\beta}}\,kr\right) J_1(kr)\, \hat{\sigma}(x_{I\!P},r) \quad (5)$$

and K_1 and J_1 are the Bessel functions. In the saturation model the dipole cross section $\hat{\sigma} = \sigma_0\,(1 - \exp(-r^2/4R_0^2(x_{I\!P}))$ where $R_0^2 \sim x_{I\!P}^\lambda$. The leading twist part is found by neglecting the factor

$$\frac{\beta}{1-\beta}\frac{k^2}{Q^2} = z(1-z) \ll 1 \quad (6)$$

under the integral in (4) and taking the upper limit of the integration to infinity. Strictly speaking, energy conservation is violated in this case, but the corrections are higher twists and are neglected because of their smallness. In Eq. (5) z, $(1-z)$ are the longitudinal momentum fractions of the final state quarks with respect to the photon momentum. Thus, the leading twist part of $F_{q\bar{q}}^T$ corresponds to the *aligned jet configurations* of the $q\bar{q}$ pair in the proton rest frame since z or $(1-z) \approx 0$. By the comparison of the leading twist part with Eq. (1) we find the *diffractive quark distribution*

$$q^D(\beta,x_{I\!P}) = \frac{3}{128\pi^4 B_D\, x_{I\!P}} \frac{\beta}{(1-\beta)^3} \int_0^\infty dk^2\; \phi_1^2(k,\beta,x_{I\!P}), \quad (7)$$

where B_D is the diffractive slope resulting from the t-integration of $F_2^{D(4)}$.

The $q\bar{q}g$ contribution was computed in [8,7] assuming strong ordering in transverse momenta of the gluon and the $q\bar{q}$ pair, i.e. $k_{\perp g} \ll k_{\perp q} \approx k_{\perp\bar{q}}$. This assumption allows to treat the $q\bar{q}g$ system as a gg dipole in the transverse configuration space r. From the point of view of the leading logarithmic contribution in Q^2 we find [9]

$$F_{q\bar{q}g}^T = 2\sum_q e_q^2\, \beta\, \frac{\alpha_s}{2\pi}\, \log\frac{Q^2}{Q_0^2} \int_\beta^1 \frac{d\beta'}{\beta'}\frac{1}{2}\left[\left(1-\frac{\beta}{\beta'}\right)^2 + \left(\frac{\beta}{\beta'}\right)^2\right] g^D(\beta,x_{I\!P})$$
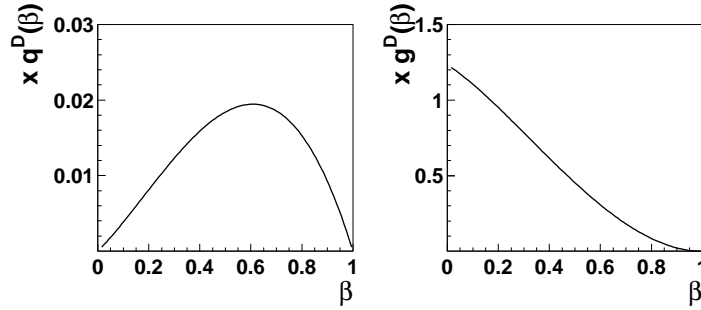$$(8)$$

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Figure 2. Diffractive quark and gluon distributions (multiplied by $x = \beta\, x_{I\!P}$) as a function of β for $x_{I\!P} = 0.0042$ at an initial scale Q_0^2.

which formula allows to define the *diffractive gluon distribution*

$$g^D(\beta, x_{I\!P}) \;=\; \frac{81}{256\pi^4 B_D\, x_{I\!P}} \; \frac{\beta}{(1-\beta)^3} \; \int_0^\infty dk^2\; \phi_2^2(k, \beta, x_{I\!P}), \qquad (9)$$

where ϕ_2 is given by Eq. (6) with the subscript 1 replaced by 2. Notice the lack of the Q^2-dependence in both (7) and (9). This may be viewed as a consequence of not having included ultraviolet divergent corrections which would require a cutoff. With those corrections the parton distributions become Q^2-dependent and evolution would relate the distributions at different Q^2. Still, we may use the found DPD as the input for the DGLAP evolution equations at some initial scale Q_0^2.

3   Regge factorization

The scaling property of the dipole cross section in the saturation model [5], i.e. that $\hat{\sigma}$ is a function of the ratio $r/R_0(x_{I\!P})$, leads to the factorized $x_{I\!P}$-dependence of the DPD, similar to Regge factorization. Introducing $\hat{k} = kR_0(x_{I\!P})$ and $\hat{r} = r/R_0(x_{I\!P})$ in (7) and (9) and assuming Q_0^2 fixed, we find

$$q^D(\beta, x_{I\!P}) = \frac{1}{x_{I\!P} R_0^2(x_{I\!P})} \; f_q(\beta) \qquad (10)$$

$$g^D(\beta, x_{I\!P}) = \frac{1}{x_{I\!P} R_0^2(x_{I\!P})} \; f_g(\beta). \qquad (11)$$

The DGLAP evolution does not affect the $x_{I\!P}$-dependence and the factorized form is valid for any scale Q^2. Thus, the leading twist part of $F_2^{D(3)}$

$$F_2^{D(3)(LT)} \;\sim\; x_{I\!P}^{-1-\lambda}, \qquad (12)$$

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where the parameter $\lambda = 0.29$ of the saturation model was found in the analysis of inclusive F_2. This value interpreted in terms of the t-averaged pomeron intercept, $F_2^{D(3)(LT)} \sim x_{I\!P}^{1-2\overline{\alpha_{I\!P}}}$, gives $\overline{\alpha_{I\!P}} = 1.15$ which is in remarkable agreement with the value 1.17 found by H1 [2] and 1.13 by ZEUS [3].

Thus, the saturation model gives effectively the result which coincides with the Regge approach to DIS diffraction, although the physics behind is completely different. The relative hardness of the intrinsic scale $1/R_0(x_{I\!P}) \sim$ 1 GeV in the saturation model suggests that DIS diffraction is a semihard process rather than a soft process as Regge theory would require.

4   Comparison with the data

We use the following model for the diffractive structure function

$$F_2^{D(3)} = F_2^{D(3)(LT)} + F_{q\bar{q}}^L, \tag{13}$$

where $F_2^{D(3)(LT)}$ is given by Eq. (1) with the DGLAP evolution from the staring conditions given by Eqs. (7) and (9), and twist-4 $F_{q\bar{q}}^L$ is defined as in the model (3), see [9] for an explicit formula. The latter contribution is crucial in the region $\beta \approx 1$. The starting point $Q_0^2 \approx 1.5$ GeV^2 for the evolution was found. to get a good description of the data. The leading $\log(Q^2)$ evolution with $N_f = 3$ flavours and $\Lambda = 200$ MeV was assumed.

The results of the comparison with the ZEUS data are presented in Fig. 3. A similar comparison with the H1 data is presented in [9]. Notice a reasonable good agreement. The description in the region of large β and Q^2, however, exhibits some problems which might be removed if such effects like twist-4 evolution or/and skewedness of the gluon distribution is taken into account.

Acknowledgments

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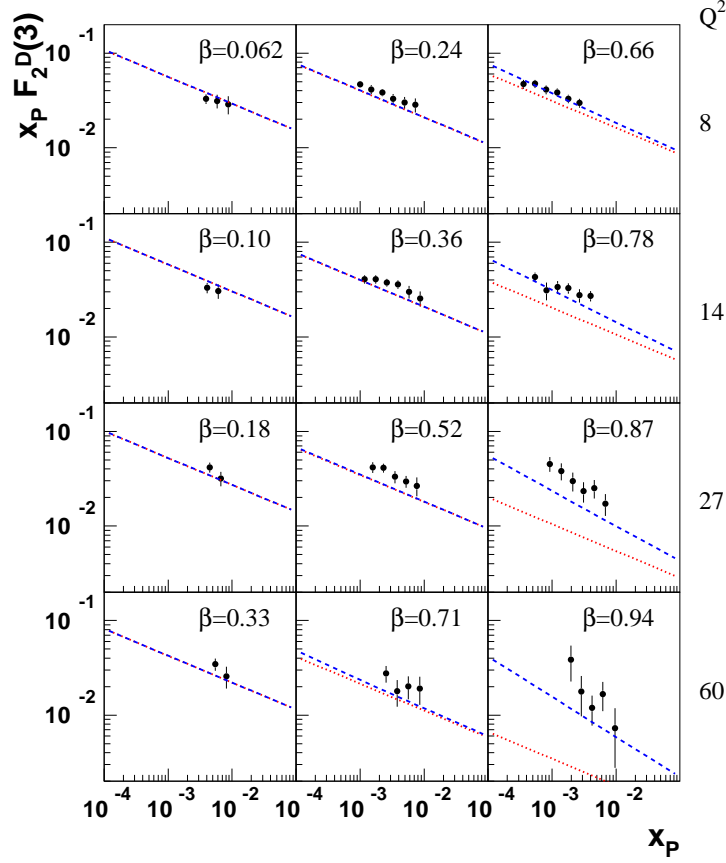3. ZEUS Collaboration, M. Derrick *et al.*, *Eur. Phys. J.* **C6** (1999) 43.

Figure 3. The comparison with ZEUS data. The dashed lines correspond to the model (13). The leading twist contribution is shown by the dotted lines.

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